Staff Report of the

CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY

REGIONAL WATER QUALITY CONTROL BOARD

CENTRAL VALLEY REGION

REVIEW OF SELENIUM CONCENTRATIONS IN WETLAND WATER SUPPLY CHANNELS IN THE GRASSLAND WATERSHED

(WATER YEARS 1999 AND 2000)

APRIL 2002

State of California

California Environmental Protection Agency

REGIONAL WATER QUALITY CONTROL BOARD
CENTRAL VALLEY REGION

Robert Schneider, Chair
Karl E. Longley, Vice Chair
Beverly Alves, Member
Alson Brizard, Member
Christopher Cabaldon, Member
Robert K. Fong, Member
Cher A. Kablanow, Member
Mark Salvaggio, Member

Gary M. Carlton, Executive Officer

3443 Routier Road, Suite A
Sacramento, California 95827-3003

Phone: (916) 255-3000
CalNet: 8-494-3000

DISCLAIMER

This publication is a technical report by staff of the California Regional Water Quality Control Board, Central Valley Region. No policy or regulation is either expressed or intended.

Staff Report of the

CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY

REGIONAL WATER QUALITY CONTROL BOARD
CENTRAL VALLEY REGION

REVIEW OF SELENIUM CONCENTRATIONS IN WETLAND WATER SUPPLY CHANNELS IN THE GRASSLAND WATERSHED

(WATER YEARS 1999 AND 2000)

APRIL 2002

REPORT PREPARED BY:
Janice Eppinger, Student Assistant
Jeanne Chilcott, Senior Environmental Scientist
San Joaquin Watershed Unit

Information presented is based on data collected by the San Joaquin Watershed Unit of the Central Valley Regional Water Quality Control Board and information provided by the U.S. Bureau of Reclamation, Grassland Area Farmers, Central California Irrigation District, Panoche Drainage District, and Redfern Ranches

Table of Contents

Page

EXECUTIVE SUMMARY 1

INTRODUCTION 4

BACKGROUND INFORMATION AND MONITORING LOCATIONS 4

DATA SOURCES AND DATA QUALITY ASSURANCE 7

HYDROLOGY 8

RESULTS AND DISCUSSION 8

Selenium in Internal Wetland Water Supply Channels: Water Years 1999 and 2000 8

Comparison to Water Year 1998 12

Comparison to Water Quality Objectives 19

Sources of Selenium 21

Supply Water 21

Subsurface Drainage from Outside the DPA 26

Other Potential Selenium Sources 27

FUTURE ACTIVITIES 27

REFERENCES 29

APPENDIX A 31

List of Tables

Table 1. Selenium Sampling Sites: Water Years 1998, 1999 and 2000 5

Table 2a. Selenium Concentrations in Wetland Supply Channels in the Grassland Watershed: Water Year 1999 10

List of Tables (continued)

Table 2b. Selenium Concentrations in Wetland Supply Channels in the Grassland Watershed: Water Year 2000 11

Table 3. Comparison of Selenium Concentrations in Agatha Canal and Camp 13 Slough: Water Years 1998, 1999 and 2000.. 17

Table 4. Comparison of Selenium Data for Selected Sites in the Grassland Watershed: Water Years 1998, 1999 and 2000 18

Table 5. Monthly Mean Selenium Concentrations at Selected Sites: Water Years 1998, 1999 and 2000 20

Table 6a. Selenium Concentrations in Supply Water for the Grassland Watershed: Water Year 1999 24

Table 6b. Selenium Concentrations in Supply Water for the Grassland Watershed: Water Year 2000 25

List of Figures

Figure 1. The Grassland Watershed Within the Lower San Joaquin River Basin 6

Figure 2. Rainfall Data from Kesterson National Wildlife Refuge: WYs 1998, 1999 and 2000 9

Figure 3. Comparison of Cumulative Rainfall at Kesterson National Wildlife Refuge: Water Years 1998, 1999 and 2000 9

Figure 4. Selenium Data Comparisons for Selected Sites in the Grassland Watershed: Water Years 1999 and 2000 14

Figure 5. Agricultural Subsurface Drainage in the Poso (Rice) Drain Area 15

Figure 6. Comparison of Selenium Concentrations at Sampling Sites on the Rice (Poso) Drain: Water Years 1999 and 2000 16

Figure 7. Selenium Concentrations in the Delta Mendota Canal at Mileposts 100.85 and 110.12 23

Figure 8. Selenium Concentrations in the CCID Main Canal at Bass Avenue (Monthly Grabs) and at Russell Avenue (Weekly Grabs): Water Years 1999 and 2000 23

Figure 9. Selenium Concentrations in CCID Main Canal as Compared to Agatha Canal and Camp 13 Slough: Water Years 1999 and 2000 26

EXECUTIVE SUMMARY

A review of selenium concentrations in wetland water supply channels in the Grassland Watershed was conducted by Regional Board staff at the completion of Water Year 1998 (Chilcott, 2000). Since that review, water quality monitoring has continued in the wetland water supply channels. This report is a compilation of the additional selenium water quality information available for the wetland water supply channels in the Grassland Watershed during Water Years 1999 and 2000 (October 1998 through September 2000).

Selenium is a naturally occurring trace element known to be hazardous to waterfowl at elevated levels. Elevated concentrations of selenium occur in the shallow groundwater in a 97,000-acre drainage project area (DPA) contained within the Grassland Watershed in the lower San Joaquin River Basin. Subsurface agricultural drainage from this area historically commingled with water used for wetland supply while being routed for discharge into the lower San Joaquin River. In September 1996, the Grassland Bypass Project (GBP) began operation and diverted the subsurface drainage from the DPA into a single channel, removing this discharge from approximately 90 miles of wetland water supply canals. Although selenium levels in the canals decreased substantially after the GBP, concentrations above the 2 ug/L selenium water quality objective adopted to protect wetland habitat have been detected in some of the canals of concern.

Elevated selenium concentrations in the supply channels during Water Year 1998 (post GBP diversions), was linked to storm water and flood flows, supply water sources, subsurface agricultural drainage from areas outside of the DPA, tail water runoff and local groundwater seepage. Of these, storm related discharges from the drainage project area (DPA) and flood flows were noted to have had a major impact during Water Year 1998. The current report focuses on selenium concentrations during Water Years 1999 and 2000. During Water Years 1999 and 2000, major storm events were absent, leaving supply water, subsurface agricultural drainage from outside of the DPA, tail water and groundwater seepage as the major influences on water quality in the internal channels.

During Water Years 1999 and 2000, selenium concentrations in three wetland water supply channels (Camp 13 Slough, Agatha Canal and Poso Drain) and two internal distribution channels (Santa Fe and San Luis Canals) were sampled weekly. Discrete weekly selenium concentrations within the channels were above 2 ug/L on a number of occasions. Unlike Water Year 1998, when selenium concentrations were concentrated during periods of extremely high flows, the elevated concentrations during Water Years 1999 and 2000 occurred sporadically throughout the two years. Maximum selenium concentrations during both years were also much lower than during Water Year 1998. For instance, maximum selenium concentrations in the Agatha Canal peaked at 40.4 ug/L in Water Year 1998, and only reached 6.4 ug/L and 2.3 ug/L in Water Years 1999 and 2000, respectively.

Comparison of the available monthly mean selenium concentrations during Water Years 1999 and 2000 to the 2 ug/L monthly mean selenium water quality objective for wetland water supply channels also showed a different pattern from wet Water Year 1998. Unlike Water Year 1998, where mean monthly selenium concentrations reached 35 ug/L during the flood months of February through early April, during Water Years 1999 and 2000 monthly means remained below 3.0 ug/L and concentrations above 2.0 ug/L were scattered throughout the years.

Major sources of supply water to the DPA and the Grassland Watershed are the Delta Mendota Canal (DMC) via the Mendota Pool and the Central California Irrigation District (CCID) Main Canal. During Water Years 1999 and 2000, the DMC, Mendota Pool and CCID Main Canal contained selenium concentrations above 2 ug/L sporadically from December through April. A close correlation between selenium concentration in internal channels and supply water selenium concentration was noted during both Water Years 1999 and 2000, particularly in the Agatha Canal and Camp 13 Slough.

Two areas have been identified where agricultural subsurface drainage can enter wetland water supply canals from farmland not contained in the DPA. One area is west of the wetland water supply channels and historically drained into the Almond Drive Drain. Since Water Year 1999, these discharges have been collected in the CCID Main Drain and diverted into the CCID Main

Canal downstream of internal supply channels. Data for Water Years 1999 and 2000 is not available for the Almond Drain site.

The second area where agricultural subsurface drainage can enter wetland water supply canals from outside the DPA is a triangle-shaped area of approximately 7,000 acres south of the Poso Drain (also known as the Rice Drain) and north of the DPA. This area historically drained into the Poso Drain, entering South GWD from the east. Three sites on the Poso (Rice) Drain were monitored for selenium during Water Years 1999 and 2000. Selenium concentrations at all three sites were above 2 ug/L a majority of the time, though a change in tail water management after June 1999 has apparently helped to reduce and stabilize concentrations. Subsurface agricultural drainage into the Poso Drain should be eliminated by January 2002 through incorporation into the Grassland Bypass Project and/or on-farm management.

Other potential sources of selenium into wetland water supply channels include tail water (surface water) runoff from irrigation and local groundwater seepage. These sources of selenium concentrations have not been evaluated to date.

To continue to evaluate the effectiveness of current control measures and guide future efforts, the following activities are anticipated:

- Continued monitoring of CCID Main Canal and other supply water on a regular basis;
- Identifying contribution of selenium from source water and subsurface drainage from outside of the DPA through special studies;
- Evaluating results to determine if additional effort is needed to identify and/or control sources of selenium into wetland supply channels within the Grassland Watershed.

Draft water quality information from the continuing studies is available on the following Central Valley Regional Water Quality Control Board web site:

http://www.swrcb.ca.gov/rwqcb5/programs/index.html

INTRODUCTION

A review of selenium concentrations in wetland water supply channels in the Grassland Watershed was conducted by Regional Board Staff at the completion of Water Year 1998 (Chilcott, 2000). Since that review, water quality monitoring has continued in the wetland water supply channels. This report is a compilation of the additional selenium water quality information available for the wetland water supply channels in the Grassland Watershed during Water Years 1999 and 2000 (October 1998 through September 2000).

BACKGROUND INFORMATION AND MONITORING LOCATIONS

Selenium is a naturally occurring trace element known to be hazardous to waterfowl at elevated levels (Skorupa, 1998). Elevated concentrations of selenium occur in the shallow groundwater in a 97,000-acre drainage project area (DPA) contained within the Grassland Watershed in the Lower San Joaquin River Basin (Chilcott, *et al.*, 1988) (**Figure 1**). Subsurface agricultural drainage from this area historically commingled with water used for wetland supply while being routed for discharge in the Lower San Joaquin River prior to September 1996. In September 1996, the Grassland Bypass Project (GBP) began operation and diverted the subsurface drainage from the DPA into a single channel, removing this discharge from approximately 90 miles of wetland water supply canals. Reducing selenium in these water bodies is a primary goal of the project (Chilcott, *et al*., 2000). In May 1996, the Central Valley Regional Water Quality Control Board adopted a 2 ug/L (monthly average) selenium water quality objective for the wetland water supply channels to protect waterfowl. This objective became effective on 10 January 1997 upon final approval by the Office of Administrative Law (RWQCB, 1998. Resolution No. 96-147, May 3, 1996).

During the initial evaluation of wetland water supply channels in 1998, available selenium water quality information for thirteen sites within the Grassland Watershed was reviewed (Chilcott, 2000). During Water Years 1999 and 2000 (WYs 99 and 00), sampling continued at the original sites with the following exceptions/additions:

- Sampling was discontinued at the Almond Drain.
- Sampling at the San Luis Canal and Santa Fe Canal sites was relocated slightly upstream of Henry Miller Road to avoid commingling.
- Sampling in the Rice (Poso) Drain expanded to three sites: at Russell Avenue; at the Boundary Drain; and at Mallard Road, each progressively downstream.
- Sampling began at three sites related to the CCID Main Canal: at the head of San Luis Canal; at the Old Main Drain; and at the CCID Main Canal at Russell Avenue.
- The US Bureau of Reclamation began monitoring the CCID Main Canal at Bass Avenue in January 1999.

Table 1 summarizes the availability of water quality data at sites monitored during Water Years 1998, 1999 and 2000, and the collecting and reporting agencies.

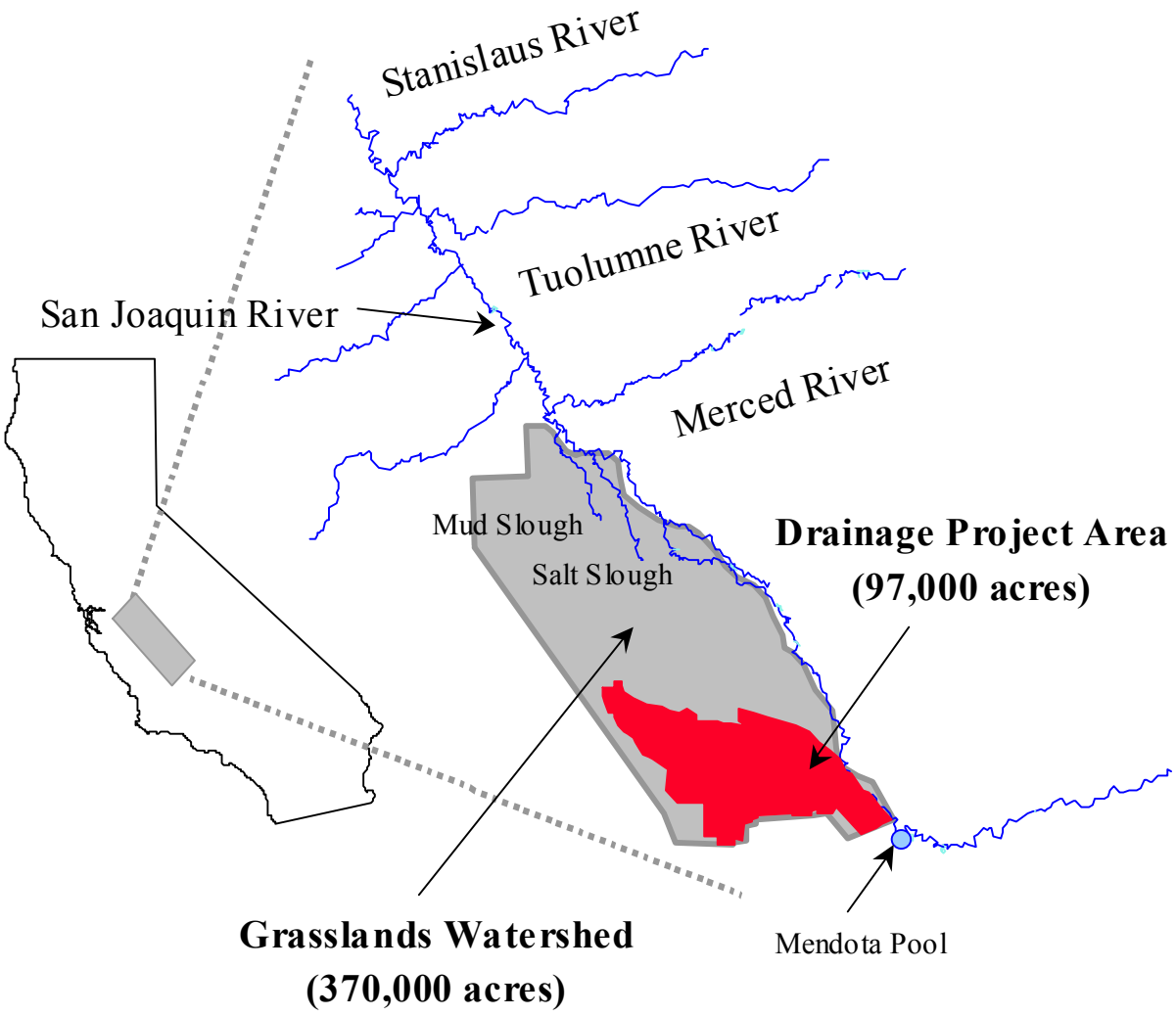
Table 1. Selenium Sampling Sites: Water Years 1998, 1999 and 2000

Data Sites	WY 98	WY 99	WY 00	Reporting Agencies[1]
Delta Mendota Canal MP100.85	M	M	M	USBR
Delta Mendota Canal MP110.12	M	M	M	USBR
Mendota Pool @ Mowry Bridge	M	M	M	CCID
CCID Main @ Bass Ave		M*	M	USBR
CCID Main @ Russell Ave	W**	W	W	PDD, CVRWQCB, CCID
CCID Main @ Head of San Luis Canal		M	M	CCID
CCID Old Main Drain @ Head of SLC		M	M	CCID
Rice (Poso) Drain @ Russell Ave	W***	W	W	CCID & Summers Engineering
Rice (Poso) Drain @ Boundary Drain		W	W	CCID & Summers Engineering
Rice (Poso) Drain @ Mallard Rd		W	W	CCID & Summers Engineering
Almond Drain - drop structure	X			CCID
Almond Drain Inflow to CCID Main nr Cotton Rd	X			CCID
Almond Drain Inflow to CCID Main nr Almond Rd	X			CCID
Camp 13 Slough	W	W	W	PDD & CVRWQCB
Agatha Canal	W	W	W	PDD & CVRWQCB
Santa Fe Canal @ Henry Miller Rd	W			PDD & CVRWQCB
San Luis Canal @ Henry Miller Rd	W			PDD & CVRWQCB
Santa Fe Canal nr Weir		W	W	PDD & CVRWQCB
San Luis Canal @ Splits		W	W	PDD & CVRWQCB

* after January 1, 1999
** after February 4, 1998
*** after March 18, 1998
W = weekly; M = monthly; X = July and August, 1998

[1] USBR = US Bureau of Reclamation
CCID = Central California Irrigation District
PDD = Panoche Drainage District
CVRWQCB = Central Valley Regional Water Quality Control Board

Figure 1: The Grassland Watershed Within the Lower San Joaquin River Basin



DATA SOURCES AND DATA QUALITY ASSURANCE

A number of agencies provided water quality information for the various sites evaluated during this study (**Table 1**). Water samples for CCID Main at Russell Avenue, Camp 13 Slough, Agatha Canal, San Luis Canal and Santa Fe Canal were collected by Panoche Drainage District weekly and transferred on ice to Regional Board staff. Staff then preserved each sample to a pH less than 2 within 24-hours of collection using 1-ml reagent grade nitric acid per 500-ml of sample. These samples were analyzed for selenium by Weck Laboratories, Inc., of Industry, California. Each set of samples submitted to Weck Laboratories included one blind split sample for every ten grab samples submitted. In addition, acidified deionized blanks, spiked blanks, and spiked matrix splits were submitted on a monthly basis. All quality assurance samples analyzed by the laboratory fell within acceptable recovery criteria for selenium before being included in the final data. Acceptable selenium recoveries were defined as: a detection limit of 0.4 ug/L; a recovery of ± 1 ug/L for concentrations between 0.4 and 10 ug/L; and a recovery of 90-110% for concentrations greater than 10 ug/L. Flow at these sites was measured by the Grassland Water District and provided to staff by Summers Engineering.

Samples from the Delta Mendota Canal sites and CCID Main at Bass Avenue were collected by US Bureau of Reclamation staff and analyzed for selenium at the Oscar Olson Biochemical Laboratory, South Dakota State University. Quality control procedures for these samples are available from US Bureau of Reclamation.

Selenium concentrations for the Rice (Poso) Drain, CCID Main at San Luis Canal, and Mendota Pool were provided by Summers Engineering and Central California Irrigation District. Selenium analyses for these samples were conducted by BSK Laboratories, of Fresno, California, which utilized its own internal quality control program.

HYDROLOGY

The San Joaquin River Index, as described in the Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (SWRCB, 1995) is used to determine a water year type in the San Joaquin River Basin. Classifications for critical, dry, below normal, above normal, or wet are based on the total unimpaired runoff from the watershed. Water Year 1999 has been classified as an above-normal water year based on unimpaired runoff of approximately 3.6 million acre feet. This classification takes into account a 20% carryover from Water Year 1998. Water Year 2000 has also been classified as an above-normal water year with 3.4-million acre feet of unimpaired runoff. Water Years 1999 and 2000 differed from Water Year 1998 in that there were no major flood events during the latter two years, rather rainfall events occurred on a consistent basis. **Figure 2** shows a daily comparison of 1999 and 2000 rainfall as compared to 1998, as measured at CIMIS Station in Kesterson National Wildlife Refuge (contained within the Grassland Watershed). **Figure 3** depicts cumulative rainfall for each of the three years at the same site. Preliminary rainfall totals for CIMIS station 92 (Kesterson) for Water Years 1998, 1999 and 2000 were 18.1 and 8.9 and 7.9 inches, respectively.

RESULTS AND DISCUSSION

Selenium in Internal Wetland Water Supply Channels: Water Years 1999 and 2000

Tables 2a and 2b summarize selenium concentrations for water samples collected weekly in selected internal wetland water supply channels. Camp 13 Slough and Agatha Canal are major supply canals for wetlands within southern GWD. Santa Fe and San Luis Canals are internal distribution channels for state, federal and private wetland habitat. The Rice Drain (Poso Drain) represents drainage from lands northeast of the DPA and may be used to supply water to some private wetland habitat downstream of Mallard Road.

Figure 2. Rainfall Data from Kesterson National Wildlife Refuge: Water Years 1998, 1999 and 2000.

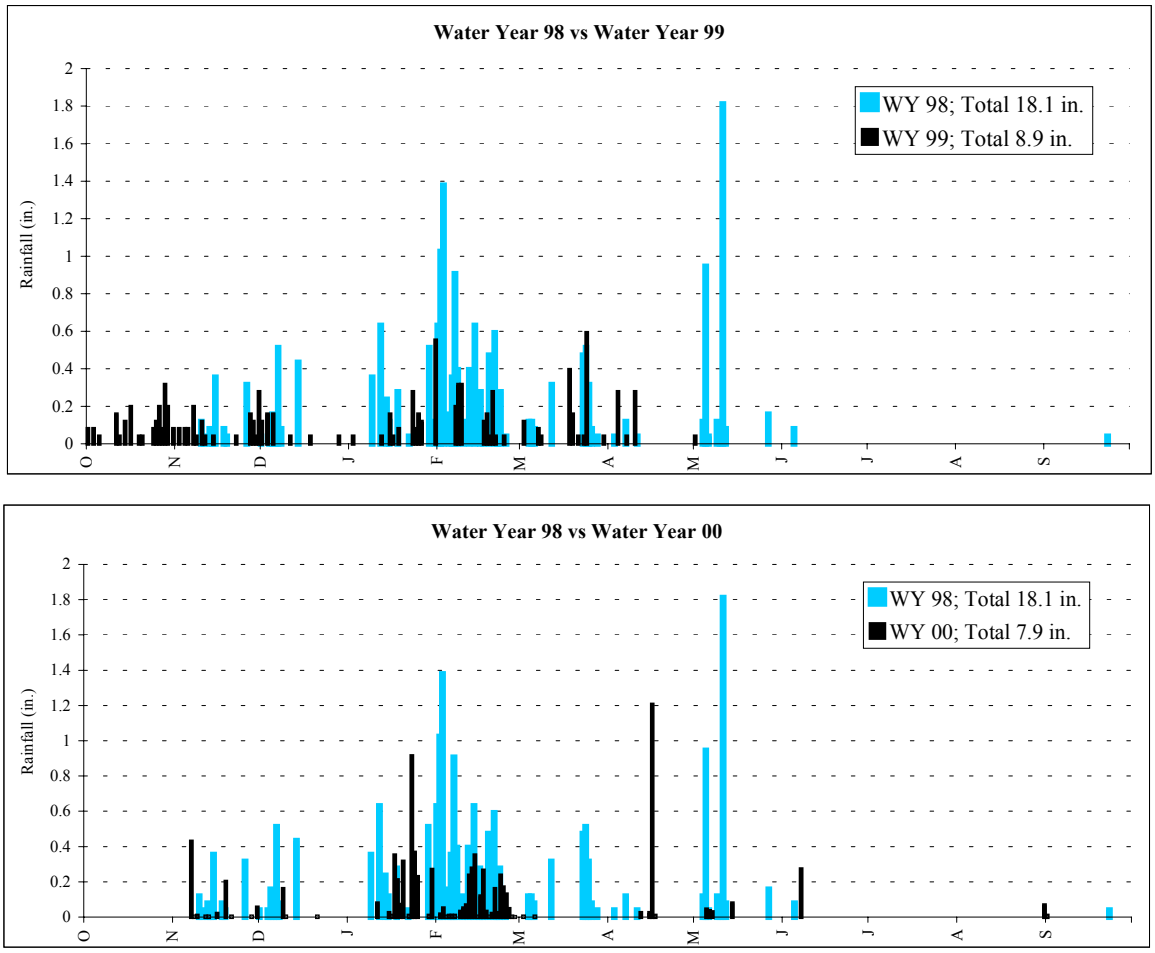


Figure 3. Comparison of Cumulative Rainfall at Kesterson National Wildlife Refuge: WYs 98, 99 and 00.

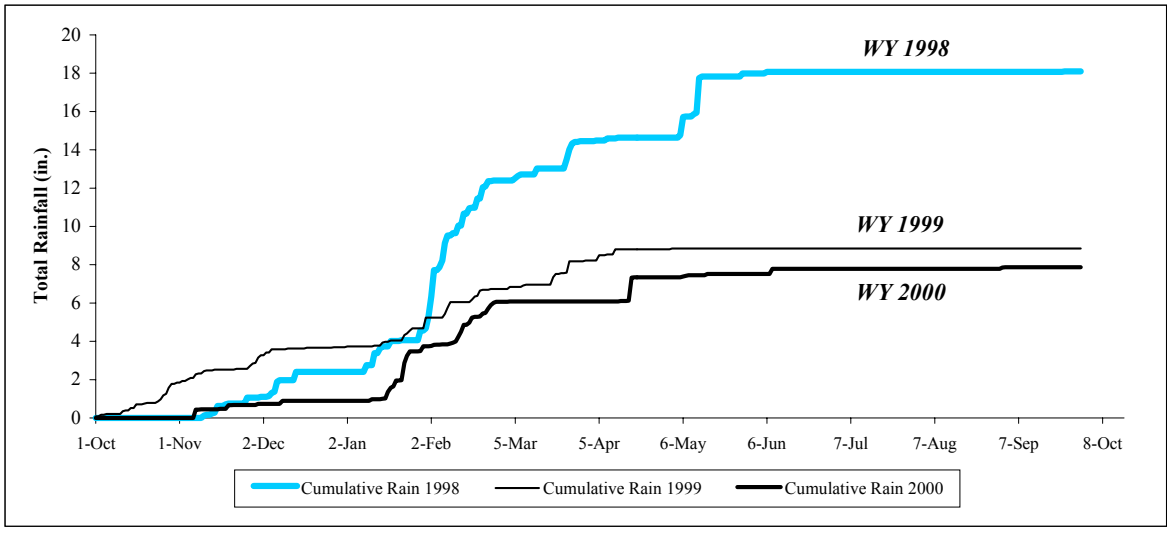


Table 2a. Selenium Concentrations in Wetland Supply Channels in the Grassland Watershed: Water Year 1999

	Selenium Concentration (ug/L)								
	Rice (Poso) Drain								
Date	at Russell	at Boundary	at Mallard	Camp 13	Agatha	SFC nr Weir	SLC @ Splits	SFC @ Henry Miller	SLC @ Henry Miller
10/07/98			<2	1.5	1.4	1.1	1.5	1.4	1.2
10/14/98			6	0.9	2.1	2.0	2.3	2.0	1.5
10/21/98			5	2.4	2.7	1.1	2.5	1.3	1.7
10/28/98	4		24	2.4	2.0	1.6	1.2	1.5	1.3
11/04/98		3	3	2.0	2.8	1.4	2.3	2.0	1.5
11/11/98	36		3	1.1	1.1	1.3	1.4	1.3	1.2
11/18/98	<2		8	1.3	1.6	1.1	1.3	1.2	1.2
11/24/98	14		<2	3.3	1.3	1.0	3.1		
12/02/98	<2		<2	1.7	0.6	0.8	1.6		
12/09/98	<2		<2	0.7	0.5	0.8	1.0		
12/16/98	3		4	<0.4	<0.4	0.8	0.5		
12/22/98	21	2	4	<0.4	<0.4	0.8	<0.4		
12/30/98	15	4	7	6.8	6.4	1.0	2.9		
01/06/99	9	<2	<2	1.3	1.0	2.2	1.4		
01/13/99	18	<2	<2	1.2	0.6	2.0	1.6		
01/20/99	10	5	4	0.9	1.1	1.1	1.3		
01/27/99	17	8	5	1.0	0.9	2.5	1.9		
02/03/99	13	<2	<2	2.0	0.9	1.0	1.9		
02/10/99	39	3	4	1.4	1.5	1.3	3.2		
02/17/99	14	<2	3	1.2	1.0	1.0	1.9		
02/24/99	29	<2	4	1.0	0.6	1.1	1.8		
03/03/99	8	2		1.1	0.7	1.3	1.9		
03/10/99	12	9	3	1.7	0.5	1.6	2.2		
03/17/99	10	9	3	2.3	0.8	1.5	1.9		
03/24/99	8	5	5	2.7	1.5	1.7	2.2		
03/31/99	7	9	<2	3.1	2.2	1.6	2.9		
04/07/99	15	10	5	2.9	3.1	1.8	2.9		
04/14/99	6	6	3	2.5	2.7	1.6	2.7		
04/21/99	4	4	5	2.3	2.0	2.0	2.6		
04/28/99	10	3	4	2.1	1.7	2.2	1.9		
05/05/99	7	<2	10	1.3	1.0	1.4	1.2		
05/12/99	4	3	3	1.8	1.4	1.7	2.1		
05/19/99	<2	30	6	1.3	1.2	1.4	1.4		
05/26/99	<2	<2	<2	1.0	1.0	1.7	1.3		
06/02/99	8	8	5	0.9	1.0	1.3	1.1		
06/09/99	17	8	5	1.3	1.0	1.8	3.0		
06/16/99	7	6	5	1.0	1.2	2.1	2.4		
06/23/99	2	3	<2	1.1	1.1	1.8	2.2		
06/30/99	8	9	6	1.2	1.1	1.9	2.4		
07/07/99	9	9	6	1.1	1.0	2.0	2.3		
07/14/99	9	7	6	1.2	1.0	1.7	2.0		
07/21/99	7	6	5	1.9	1.0	2.1	2.1		
07/28/99	6	5	4	0.9	0.8	1.6	2.1		
08/04/99	7	6	6	1.1	0.8	2.5	1.7		
08/11/99	4	5	4	1.2	0.9	2.1	1.5		
08/18/99	5	3	3	1.3	0.8	2.5	1.5		
08/25/99	6	6	4	1.4	1.3	2.1	1.6		
09/01/99	5	5	4	1.3	1.3	1.6	1.4		
09/08/99	<2	<2	<2	2.7	2.1	1.8	2.5		
09/15/99	5	3	4	1.3	1.1	1.2	1.7		
09/22/99	7	5	2	0.7	0.8	1.0	1.1		
09/29/99	10	6	6	0.7	2.1	1.7	0.9		

Almond Drive Drain sites no longer being sampled; Henry Miller Avenue sites discontinued after 11/18/98.

Rice Drain data provided by Summers Engineering; analyses by BSK, Fresno CA

Other data provided by CVRWQCB; samples taken by Panoche WD; analyses by Weck Labs, Industry CA

SFC = Santa Fe Canal SLC = San Luis Canal

Table 2b. Selenium Concentrations in Wetland Supply Channels in the Grassland Watershed: Water Year 2000

	Selenium Concentration (ug/L)						
	Rice (Poso) Drain					SFC nr	SLC @
Date	at Russell	at Boundary	at Mallard	Camp 13	Agatha	Weir	Splits
10/06/99	4	4	na	1.2	0.6	1.3	0.9
10/13/99				1.1	1.0	0.8	0.9
10/20/99	12	<2	<2	0.6	0.9	0.9	1.1
10/27/99	6	<2	2	1.3	1.2	0.8	0.9
11/03/99	6	5	2	1.6	1.3	0.8	1.5
11/11/99	3	3	4	1.8	1.8	0.7	1.1
11/17/99	2	<2	<2	1.3	1.2	0.9	1.6
11/22/99	<2	<2	<2	1.2	1.1	0.8	1.6
12/01/99	2	<2	<2	<0.4	0.6	0.7	0.8
12/08/99	<2	3	5	2.2	0.5	1.3	1.3
12/15/99	<2	<2	<2	0.5	0.7	1.1	1.8
12/20/99	6	6	8	0.6	1.0	0.8	0.5
12/27/99	3	3	<2	0.9	1.0	0.9	0.8
01/05/00	2	4	<2	<0.4	<0.4	0.5	<0.4
01/12/00	2	2	<2	1.2	0.5	0.5	1.0
01/19/00	4	4	3	0.5	0.7	0.6	0.8
01/26/00	5	2	<2	1.6	1.2	0.8	1.3
02/02/00	12	13	5	1.6	1.0	0.9	3.3
02/09/00	<2	<2	<2	1.7	0.9	1.8	3.6
02/16/00	8	4	2	2.1	1.5	1.9	2.1
02/23/00	16	14	21	2.8	2.0	1.8	2.4
03/01/00	17	7	19	2.6	1.9	2.4	3.5
03/08/00	16	10	9	1.4	0.9	1.3	1.6
03/15/00	11	8	21	1.9	1.8	1.2	2.1
03/22/00	4	4	3	0.6	0.5	1.1	1.1
03/29/00	4	4	<2	0.5	0.5	0.5	0.6
04/05/00	3	4	3	2.3	2.2	1.2	2.7
04/12/00	5	3	5	1.9	1.0	1.4	1.3
04/19/00	5	4	4	2.0	1.8	2.3	1.8
04/26/00	2	3	2	2.0	2.3	2.0	2.4
05/03/00	4	3	3	1.8	1.5	2.3	1.7
05/10/00	5	4	2	1.5	1.7	2.1	2.0
05/17/00	10	5	4	1.5	1.2	1.5	1.5
05/24/00	11	9	7	1.9	1.3	1.5	1.5
05/31/00	8	7	7	1.5	1.2	1.8	1.5
06/07/00	8	8	7	1.7	1.6	2.1	2.0
06/14/00	8	5	4	1.6	1.4	1.8	2.6
06/21/00	8	6	4	1.7	1.5	1.7	2.7
06/28/00	6	5	4	1.1	1.2	2.2	2.3
07/05/00	7	5	6	1.3	1.0	2.5	2.2
07/12/00	5	6	4	1.0	0.7	1.7	2.2
07/19/00	5	5	4	1.3	1.1	1.8	2.3
07/26/00	na	na	na	1.3	1.2	2.0	2.6
08/02/00	5	4	3	0.8	0.8	1.8	1.8
08/09/00	6	5	4	0.9	0.9	1.9	1.8
08/16/00	6	5	4	1.4	0.8	1.4	1.8
08/23/00	6	5	4	0.9	0.8	1.8	1.7
08/30/00	3	3	2	0.5	<0.4	0.7	0.8
09/06/00	4	3	2	<0.4	<0.4	0.5	0.4
09/13/00	4	5	4	0.6	0.7	0.5	0.6
09/20/00	6	4	2	1.2	0.9	1.0	0.8
09/27/00	12	11	8	0.8	1.0	2.0	1.8

Rice Drain data provided by Summers Engineering; analyses by BSK, Fresno CA

Other data provided by CVRWQCB; samples taken by Panoche WD; analyses by Weck Labs, Industry CA

SFC = Santa Fe Canal SLC = San Luis Canal

Figure 4 depicts selenium concentration in Camp 13, Agatha, Santa Fe and San Luis Canals during Water Years 1999 and 2000. Selenium concentration trends appear similar in all the channels represented. During Water Year 1999, the discrete weekly selenium concentrations in Camp 13 and Agatha Canals were above 2 ug/L in October, November and December 1998 and again in March and April 1999, with spikes of 6.8 ug/L at Camp 13 and 6.4 ug/L at Agatha in late December 1998. During Water Year 2000, discrete weekly selenium concentrations in the two channels did not exceed 2.8 ug/L.

Weekly selenium concentrations in the San Luis Canal and Santa Fe Canal above 2 ug/L occurred sporadically throughout Water Year 1999, but only occurred from early February to late July in Water Year 2000. Maximum concentrations reached 3.2 ug/L in Water Year 1999 and 3.6 ug/L in Water Year 2000.

Figure 5 indicates the relative locations of the three Poso (Rice) Drain sampling points during Water Years 1999 and 2000: at Russell Avenue; at the Boundary Drain; and at Mallard Road, moving progressively downstream. Water samples were collected at the three sites weekly by the Grassland Area Farmers (GAF). A graphic comparison of selenium concentrations at the three sites is presented in **Figure 6**. Based on the results reported by the GAF (Summers, 1999 and 2001), weekly selenium concentrations at all three sites were above 2 ug/L almost continually during both water years, ranging from <2 ug/L to 39 ug/L. The highest concentration (39 ug/L in February) and highest mean concentration (10 ug/L) was recorded at the Russell Avenue site during Water Year 1999. During Water Year 2000, selenium concentrations at Russell Avenue decreased substantially with a mean of 6 ug/L. The maximum selenium concentration recorded during Water Year 2000 was 21 ug/L at the Mallard Road site in February and March.

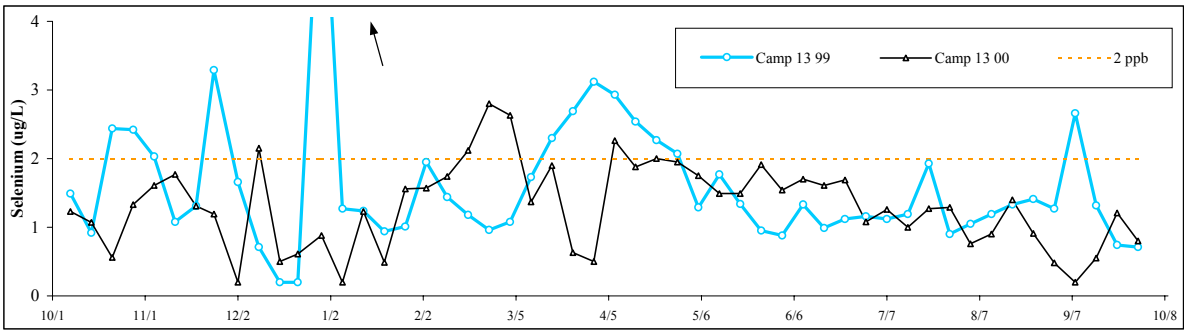
Comparison to Water Year 1998

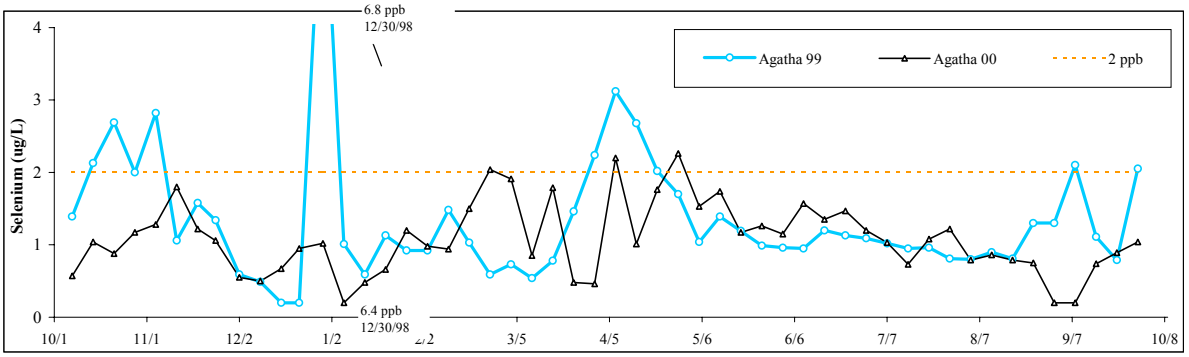
During Water Year 1998, selenium concentrations greater than 2 ug/L in the Grassland Watershed tended to be associated with storm runoff during unusually high rainfall in January and February of 1998 (Figure 3). During Water Years 1999 and 2000, although there was above

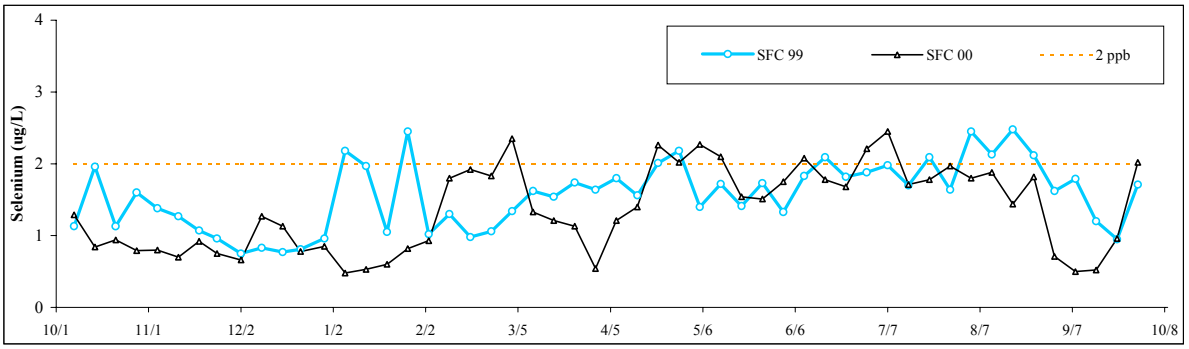
normal rainfall, there were no large storm events. The selenium concentrations in turn, were lower overall and concentrations above 2 ug/L were scattered throughout the two years. While the reported values tend to indicate lower overall selenium concentrations in the Grassland channels during the non-flood years of 1999 and 2000, if the data for each year is examined *without considering February and March*, the two months during which the selenium concentrations were greatly impacted by flood flows in Water Year 1998, the annual mean concentrations for all three water years are fairly consistent ranging between 1.0 and 2.0 ug/L depending on the location and time of year (**Appendix A**).

Tables 3 and 4 compare selenium concentrations from Water Years 1998, 1999 and 2000 in Camp 13 Slough and the Agatha, CCID Main, Santa Fe, and San Luis Canals. The maximum and mean selenium values for Water Years 1999 and 2000 tend to be lower at all these sites than during Water Year 1998. (Comparable data for the Rice Drain was not available for Water Year 1998.) Although selenium concentrations were occasionally above 2 ug/L during Water Years 1999 and 2000, the maximum concentration in the channels was much less than those seen during the flooding in Water Year 1998 (e.g. the maximum concentration in Agatha Canal during Water Year 1998 was 40.4 ug/L as opposed to a maximum of 6.4 ug/L in Water Year 1999.)

Figure 4. Selenium Data Comparisons for Selected Sites in the Grassland Watershed: Water Years 1999 and 2000.







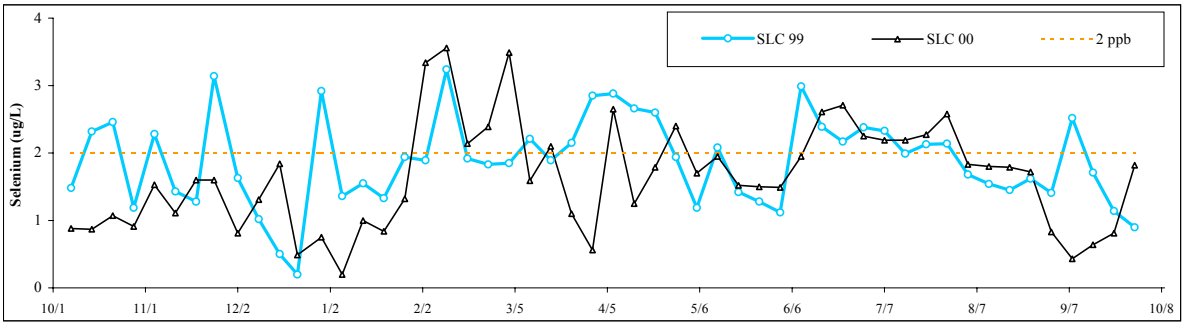


Figure 5: Agricultural Subsurface Drainage in the Poso (Rice) Drain Area

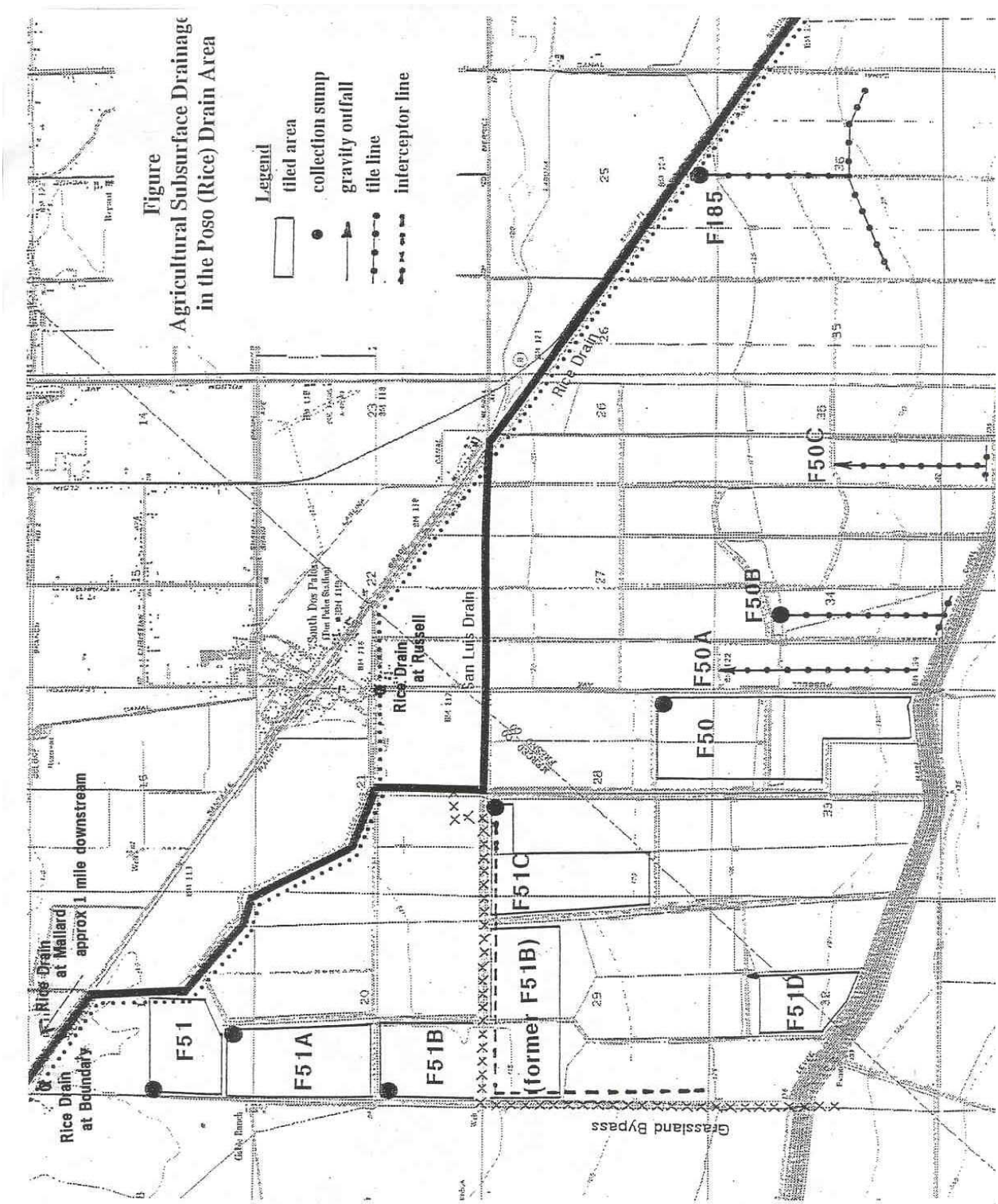


Figure 6. Comparison of Selenium Concentrations at Sampling Sites on the Rice (Poso) Drain: Water Years 1999 and 2000.

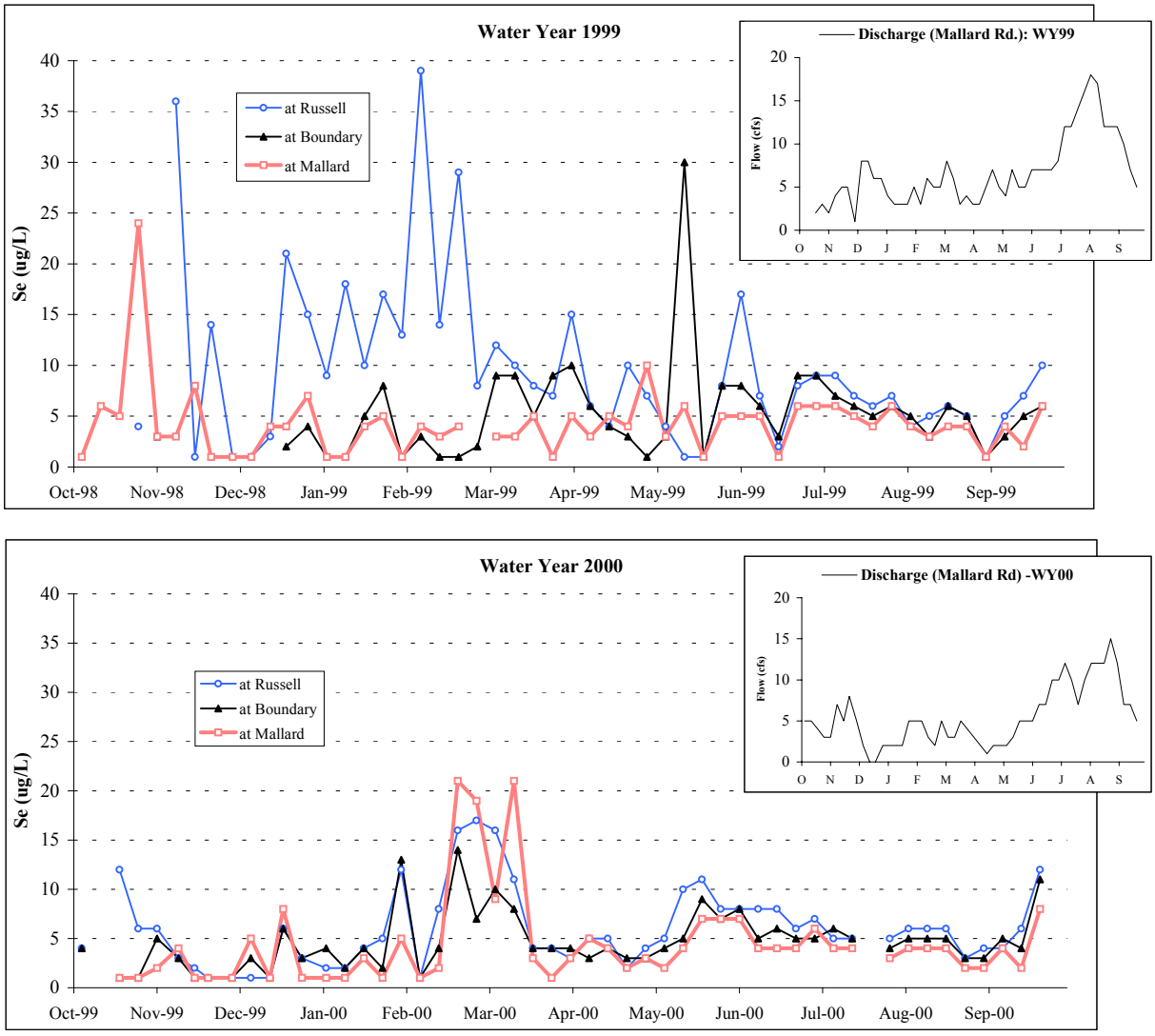


Table 3. Comparison of Selenium Concentrations in Agatha Canal and Camp 13 Slough: Water Years 1998, 1999 and 2000.

Date			Selenium Concentration (ug/L)					
			Camp 13 Slough			Agatha Canal		
WY 98	WY 99	WY 00	WY 98	WY 99	WY 00	WY 98	WY 99	WY 00
10/8/97	10/7/98	10/6/99	1.1	1.5	1.2	0.8	1.4	0.6
10/15/97	10/14/98	10/13/99	1.0	0.9	1.1	0.7	2.1	1.0
10/22/97	10/21/98	10/20/99	0.8	2.4	0.6	0.8	2.7	0.9
10/29/97	10/28/98	10/27/99	0.8	2.4	1.3	1.0	2.0	1.2
11/5/97	11/4/98	11/3/99	0.8	2.0	1.6	0.7	2.8	1.3
11/12/97	11/11/98	11/11/99	0.7	1.1	1.8	0.9	1.1	1.8
11/19/97	11/18/98	11/17/99	1.6	1.3	1.3	1.8	1.6	1.2
11/25/97	11/24/98	11/22/99	1.6	3.3	1.2	1.7	1.3	1.1
12/3/97	12/2/98	12/1/99	8.4	1.7	<0.4	1.9	0.6	0.6
12/10/97	12/9/98	12/8/99	5.2	0.7	2.2	0.9	0.5	0.5
12/17/97	12/16/98	12/15/99	8.9	<0.4	0.5	1.5	<0.4	0.7
12/23/97	12/22/98	12/20/99	1.6	<0.4	0.6	0.9	<0.4	1.0
12/30/97	12/30/98	12/27/99	0.8	6.8	0.9	5.9	6.4	1.0
1/7/98	1/6/99	1/5/00	1.0	1.3	<0.4	0.7	1.0	<0.4
1/14/98	1/13/99	1/12/00	1.2	1.2	1.2	1.2	0.6	0.5
1/21/98	1/20/99	1/19/00	1.7	0.9	0.5	1.6	1.1	0.7
1/28/98	1/27/99	1/26/00	1.6	1.0	1.6	1.5	0.9	1.2
2/4/98	2/3/99	2/2/00	2.8	2.0	1.6	27.0	0.9	1.0
2/11/98	2/10/99	2/9/00	4.0	1.4	1.7	39.2	1.5	0.9
2/18/98	2/17/99	2/16/00	3.3	1.2	2.1	36.4	1.0	1.5
2/25/98	2/24/99	2/23/00	1.8	1.0	2.8	40.4	0.6	2.0
3/4/98	3/3/99	3/1/00	3.4	1.1	2.6	3.5	0.7	1.9
3/11/98	3/10/99	3/8/00	4.0	1.7	1.4	3.9	0.5	0.9
3/18/98	3/17/99	3/15/00	3.5	2.3	1.9	1.1	0.8	1.8
3/25/98	3/24/99	3/22/00	1.7	2.7	0.6	1.5	1.5	0.5
4/1/98	3/31/99	3/29/00	11.5	3.1	0.5	2.8	2.2	0.5
4/8/98	4/7/99	4/5/00	9.8	2.9	2.3	1.8	3.1	2.2
4/15/98	4/14/99	4/12/00	7.3	2.5	1.9	2.2	2.7	1.0
4/22/98	4/21/99	4/19/00	1.7	2.3	2.0	2.3	2.0	1.8
4/29/98	4/28/99	4/26/00	1.1	2.1	2.0	1.9	1.7	2.3
5/6/98	5/5/99	5/3/00	1.6	1.3	1.8	1.4	1.0	1.5
5/13/98	5/12/99	5/10/00	1.6	1.8	1.5	1.0	1.4	1.7
5/20/98	5/19/99	5/17/00	1.3	1.3	1.5	0.9	1.2	1.2
5/27/98	5/26/99	5/24/00	0.8	1.0	1.9	1.0	1.0	1.3
6/3/98	6/2/99	5/31/00	1.7	0.9	1.5	0.7	1.0	1.2
6/10/98	6/9/99	6/7/00	2.5	1.3	1.7	0.7	1.0	1.6
6/17/98	6/16/99	6/14/00	1.8	1.0	1.6	0.6	1.2	1.4
6/24/98	6/23/99	6/21/00	1.0	1.1	1.7	0.6	1.1	1.5
7/1/98	6/30/99	6/28/00	0.7	1.2	1.1	0.3	1.1	1.2
7/8/98	7/7/99	7/5/00	0.3	1.1	1.3	0.3	1.0	1.0
7/15/98	7/14/99	7/12/00	0.3	1.2	1.0	0.2	1.0	0.7
7/22/98	7/21/99	7/19/00	2.6	1.9	1.3	0.4	1.0	1.1
7/29/98	7/28/99	7/26/00	1.0	0.9	1.3	1.5	0.8	1.2
8/5/98	8/4/99	8/2/00	1.3	1.1	0.8	1.4	0.8	0.8
8/12/98	8/11/99	8/9/00	2.0	1.2	0.9	1.3	0.9	0.9
8/19/98	8/18/99	8/16/00	2.1	1.3	1.4	1.1	0.8	0.8
8/26/98	8/25/99	8/23/00	1.3	1.4	0.9	1.2	1.3	0.8
9/2/98	9/1/99	8/30/00	1.1	1.3	0.5	1.2	1.3	<0.4
9/9/98	9/8/99	9/6/00	1.5	2.7	<0.4	1.5	2.1	<0.4
9/16/98	9/15/99	9/13/00	1.0	1.3	0.6	1.1	1.1	0.7
9/23/98	9/22/99	9/20/00	1.1	0.7	1.2	1.5	0.8	0.9
9/30/98	9/29/99	9/27/00	0.7	0.7	0.8	0.7	2.1	1.0
		Count	52	52	52	52	52	52
		Min	0.3	<0.4	<0.4	0.2	<0.4	<0.4
		Max	11.5	6.8	2.8	40.4	6.4	2.3
		Mean	2.4	1.6	1.3	4.0	1.4	1.1
		Geo Mean	1.7	1.4	1.1	1.5	1.1	1.0
		Median	1.6	1.3	1.3	1.2	1.1	1.0

Table 4. Comparison of Selenium Concentrations for Selected Sites in the Grassland Watershed: Water Years 1998, 1999 and 2000

	Selenium Concentration (ug/L)								
	CCID Main @ Russell			Santa Fe Canal			San Luis Canal		
Date*	WY 98	WY 99	WY 00	WY 98	WY 99	WY 00	WY 98	WY 99	WY 00
10/7		0.9	0.8	1.3	1.1	1.3	1.7	1.5	0.9
10/14		1.9	1.1	1.6	2.0	0.8	2.1	2.3	0.9
10/21		1.2	1.0	1.3	1.1	0.9	2.0	2.5	1.1
10/28	0.7	1.5	0.6	1.1	1.6	0.8	1.1	1.2	0.9
11/4		1.0	0.6	0.9	1.4	0.8	0.8	2.3	1.5
11/11		2.3	1.2	1.1	1.3	0.7	1.1	1.4	1.1
11/18		1.7	1.1	1.1	1.1	0.9	1.4	1.3	1.6
11/24		2.9	1.7	1.1	1.0	0.8	2.0	3.1	1.6
12/2		1.2	0.8	2.9	0.8	0.7	7.2	1.6	0.8
12/9		<0.4	1.6	1.17	0.8	1.3	2.03	1.0	1.3
12/16		<0.4	1.0	1.14	0.8	1.1	1.3	0.5	1.8
12/22		<0.4	1.0	1.4	0.8	0.8	1.4	<0.4	0.5
12/30		3.2	1.0	1.3	1.0	0.9	1.2	2.9	0.8
1/6		0.7	0.8	1.0	2.2	0.5	1.0	1.4	<0.4
1/13		0.9	0.8	1.4	2.0	0.5	1.8	1.6	1.0
1/20		1.1	2.0	0.9	1.1	0.6	1.4	1.3	0.8
1/27		1.8	1.0	1.3	2.5	0.8	1.5	1.9	1.3
2/3	3.1	2.5	1.2	7.3	1.0	0.9	5.1	1.9	3.3
2/10	3.6	1.5	2.3	13.0	1.3	1.8	8.3	3.2	3.6
2/17	2.8	1.4	1.5	11.6	1.0	1.9	8.9	1.9	2.1
2/24	2.8	1.0	1.3	8.0	1.1	1.8	10.5	1.8	2.4
3/3	3.9	2.0	1.3	3.6	1.3	2.4	4.0	1.9	3.5
3/10	2.4	1.8	2.2	5.4	1.6	1.3	5.4	2.2	1.6
3/17	1.4	2.0	1.0	4.1	1.5	1.2	4.3	1.9	2.1
3/24	1.5	2.5	0.7	2.8	1.7	1.1	3.0	2.2	1.1
3/31	3.6	2.5	0.6	3.3	1.6	0.5	3.2	2.9	0.6
4/7	3.4	2.7	1.5	3.4	1.8	1.2	3.3	2.9	2.7
4/14	2.2	2.7	1.3	3.1	1.6	1.4	3.4	2.7	1.3
4/21	1.1	1.9	1.7	1.8	2.0	2.3	1.8	2.6	1.8
4/28	1.0	1.5	1.9	1.7	2.2	2.0	1.4	1.9	2.4
5/5	1.3	0.9	1.5	1.6	1.4	2.3	1.8	1.2	1.7
5/12	0.8	1.3	1.5	1.5	1.7	2.1	2.0	2.1	2.0
5/19	0.6	1.2	1.1	1.9	1.4	1.5	1.5	1.4	1.5
5/26	0.6	1.1	1.0	2.0	1.7	1.5	1.6	1.3	1.5
6/2	0.7	0.8	1.2	1.2	1.3	1.8	1.5	1.1	1.5
6/9	0.6	0.8	1.4	1.0	1.8	2.1	1.5	3.0	2.0
6/16	1.1	1.0	1.5	1.2	2.1	1.8	1.4	2.4	2.6
6/23	1.1	1.0	1.4	1.2	1.8	1.7	1.6	2.2	2.7
6/30	<0.4	1.2	1.2	1.7	1.9	2.2	1.1	2.4	2.3
7/7	<0.4	0.9	1.0	0.7	2.0	2.5	1.6	2.3	2.2
7/14	<0.4	0.8	1.1	1.1	1.7	1.7	1.6	2.0	2.2
7/21	0.9	0.8	1.3	1.5	2.1	1.8	2.6	2.1	2.3
7/28	0.8	0.8	1.3	1.9	1.6	2.0	2.5	2.1	2.6
8/4	1.2	1.0	0.7	2.1	2.5	1.8	2.2	1.7	1.8
8/11	0.9	0.9	1.0	1.6	2.1	1.9	2.0	1.5	1.8
8/18		0.84	0.5	1.8	2.5	1.4	3.0	1.5	1.8
8/25	0.8	1.03	0.71	1.4	2.1	1.8	1.8	1.6	1.7
9/1	1.1	1.2	<0.4	1.8	1.6	0.7	1.5	1.4	0.8
9/8	0.9	1.52	0.48	1.7	1.8	0.5	1.9	2.5	0.4
9/15	1.2	1.19	0.68	1.2	1.2	0.5	1.2	1.7	0.6
9/22	1.7	0.86	0.65	1.6	1.0	1.0	1.4	1.1	0.8
9/29	1.3	1.07	1.6	1.1	1.7	2.0	1.1	0.9	1.8
Count	**35**	**52**	**52**	**52**	**52**	**52**	**52**	**52**	**52**
Min	**<0.4**	**<0.4**	**<0.4**	**0.7**	**0.8**	**0.5**	**0.8**	**<0.4**	**<0.4**
Max	**3.9**	**3.2**	**2.3**	**13.0**	**2.5**	**2.5**	**10.5**	**3.2**	**3.6**
Mean	**1.5**	**1.4**	**1.1**	**2.4**	**1.6**	**1.4**	**2.5**	**1.9**	**1.6**
Geo Mean	**1.1**	**1.2**	**1.1**	**1.8**	**1.5**	**1.2**	**2.1**	**1.7**	**1.4**
Median	**1.1**	**1.2**	**1.1**	**1.6**	**1.6**	**1.3**	**1.8**	**1.9**	**1.6**

* Date approximate to within three days

Comparison to Water Quality Objectives

In May 1996, the Central Valley Regional Water Quality Control Board adopted a 2 ug/L (monthly mean) selenium water quality objective for wetland water supply channels to protect waterfowl. The channels were identified by name and location in the basin plan amendment (RWQCB, 1998). The 2 ug/L selenium objective for these channels became effective on 10 January 1997 upon final approval by the Office of Administrative Law.

Table 5 presents the monthly mean concentrations of selenium at CCID Main Canal, Agatha Canal, Camp 13 Slough, San Luis Canal at Henry Miller Road (WY 98 only) and at the splits, Santa Fe Canal at Henry Miller Road (WY 98 only) and at the splits, and available Poso Drain data for Water Years 1999 and 2000. The data presented is compared to the 2 ug/L monthly mean water quality objective for wetland water supply channels. Unlike Water Year 1998, during Water Years 1999 and 2000, maximum monthly mean selenium concentrations remained below 3.0 ug/L and occurred somewhat randomly throughout the year. The exception was the Poso (Rice) Drain at Mallard whose monthly mean selenium concentrations were consistently above 2.0 ug/L and reached 10.6 ug/L in March 2000.

Table 5. Monthly Mean Selenium Concentrations at Selected Sites: Water Years 1998, 1999 and 2000

CVRWQCB Site ID	Description	Mean Monthly Concentration (ug/L) - WY 98											
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
MER510	CCID Main Supply @ Russell					3.1	2.3	2.3	0.8	0.9	0.5	1.0	1.2
MER505	Camp 13 Ditch	0.9	1.2	5.0	1.4	**3.0**	**3.2**	**6.3**	1.3	1.8	0.9	1.7	1.1
MER506	Agatha Canal	0.8	1.3	**2.2**	1.3	**35.8**	**2.5**	**2.2**	1.1	0.7	0.5	1.3	1.2
MER532	San Luis Canal at Henry Miller Rd	1.8	1.3	**2.6**	1.4	**8.2**	**4.2**	**2.6**	1.7	1.5	2.0	**2.3**	1.4
MER519	Santa Fe Canal at Henry Miller Rd	1.5	1.1	1.6	1.2	**10.0**	**4.0**	**2.7**	1.8	1.2	1.3	1.7	1.5
MER509	Poso Drain @ Mallard	no data available											
*	Poso Drain @ Russell	no data available											
*	Poso Drain @ Boundary	no data available											

CVRWQCB Site ID	Description	Mean Monthly Concentration (ug/L) - WY 99											
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
MER510	CCID Main Supply @ Russell	1.4	2.0	1.0	1.1	1.6	2.2	2.2	1.1	0.9	0.8	0.9	1.2
MER505	Camp 13 Ditch	1.8	1.9	1.9	1.1	1.4	**2.2**	**2.5**	1.3	1.1	1.3	1.2	1.3
MER506	Agatha Canal	**2.1**	1.7	1.6	0.9	1.0	1.2	**2.4**	1.2	1.1	0.9	1.0	1.5
MER563	San Luis Canal at Splits	1.9	2.0	1.2	1.5	**2.2**	**2.2**	**2.5**	1.5	**2.2**	**2.1**	1.6	1.5
MER545	Santa Fe Canal at Weir	1.5	1.2	0.6	1.9	1.1	1.6	1.9	1.6	1.8	1.9	**2.3**	1.5
MER509	Poso Drain @ Mallard	**9.0**	**3.8**	**3.4**	**2.8**	**3.0**	**3.0**	**4.3**	**5.0**	**4.4**	**5.3**	**4.3**	**3.4**
*	Poso Drain @ Russell	4.0	17.0	8.2	13.5	23.8	9.0	8.8	3.3	8.4	7.8	5.5	5.6
*	Poso Drain @ Boundary		3.0	3.0	3.8	1.5	6.8	5.8	8.8	6.8	6.8	5.0	4.0

CVRWQCB Site ID	Description	Mean Monthly Concentration (ug/L) - WY 00											
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
MER510	CCID Main Supply @ Russell	0.9	1.2	1.1	1.2	1.6	1.1	1.6	1.3	1.4	1.1	0.6	0.9
MER505	Camp 13 Ditch	1.0	1.5	0.7	0.9	**2.1**	1.4	2.0	1.7	1.5	1.2	0.9	0.7
MER506	Agatha Canal	0.9	1.3	0.5	0.6	1.4	1.1	1.8	1.4	1.4	1.0	0.7	0.6
MER563	San Luis Canal at Splits	0.9	1.5	0.7	0.8	**2.9**	1.8	2.0	1.6	**2.4**	**2.3**	1.6	0.9
MER545	Santa Fe Canal at Weir	1.0	0.8	0.9	0.6	1.6	1.3	1.7	1.8	1.9	2.0	1.5	1.0
MER509	Poso Drain @ Mallard	1.5	2.0	**3.2**	1.5	**7.3**	**10.6**	**3.5**	**4.6**	**4.8**	**4.7**	**3.4**	**4.0**
*	Poso Drain @ Russell	7.3	3.0	2.6	3.3	9.3	10.4	3.8	7.6	7.5	5.7	5.2	6.5
*	Poso Drain @ Boundary	2.0	2.5	2.8	3.0	8.0	6.6	3.5	5.6	6.0	5.3	4.4	5.8

* upstream of identified wetland water supply channel

bold = selenium concentration exceeding 2 ug/L Water Quality Objective

Sources of Selenium

The primary source of selenium in the Grassland Watershed is from subsurface agricultural drainage in the DPA, all of which has now been rerouted around wetland water supply channels except during periods of exceptionally high rainfall and flooding. Potential additional sources of selenium were identified in Chilcott (2000) and include supply water, discharges from the DPA, subsurface agricultural drainage from areas outside of the DPA, storm water and flood flows, tail water runoff and local groundwater seepage. Of these, storm-related discharges from the DPA and flood flows were noted to have had a major impact during Water Year 1998. During Water Years 1999 and 2000, major storm events were absent, leaving the remaining sources as the major influences on water quality in the wetland water supply channels.

Supply Water

The major supply water sources to the Grassland Watershed are seasonal storm water runoff from the Coast Range and water imported from the Delta for irrigation and wetland habitat. Water from the Delta is imported through the Delta Mendota Canal (DMC) and flows in a southeasterly direction, into the Mendota Pool. The Mendota Pool in turn feeds the CCID Main Canal,

Outside Canal and other supply laterals which flow northwest and are used to supply water for irrigation and wetland habitat. Additional inflow to the supply system may occur from surface tailwater return flows and some groundwater pumping.

Tables 6a and 6b summarize selenium concentrations in major water supply sources during Water Years 1999 and 2000: the DMC at Mileposts 100.85 and 110.12; the Mendota Pool at Mowry Bridge; and the CCID Main Canal at Bass Avenue, at Russell Avenue, and at the head of the San Luis Canal. DMC Mileposts 100.85 and 110.12 represent locations upstream and downstream, respectively, of inflows from six shallow groundwater sumps. In addition, the tables list selenium concentrations in the CCID Old Main Drain near the head of the San Luis Canal. The CCID Old Main Drain discharges into the CCID Main Canal downstream of the diversion to the San Luis Canal.

The Delta Mendota Canal was sampled monthly by the US Bureau of Reclamation at two locations during Water Years 1999 and 2000. Out of the 48 sampling events, selenium concentrations were reported above 2 ug/L eleven times. The highest annual concentrations of selenium at Milepost 100.85 were 8.6 ug/L in December of Water Year 1999 and 2.5 ug/L in January of Water Year 2000. Milepost 110.12 reached a high of 11 ug/L selenium in December of Water Year 1999 and 14.6 ug/L in January of Water Year 2000 (**Figure 7**). The Mendota Pool had selenium concentrations above 2 ug/L in March of Water Year 1999 and in April of Water Year 2000 (Tables 6a and 6b).

The CCID Main Canal at Bass Avenue (sampled monthly) also had selenium concentrations greater than 2 ug/L in April of both water years as well as a maximum of 7.2 ug/L in January 2000. Selenium concentrations at the CCID Main Canal at Russell (sampled weekly) were above 2 ug/L in eight of the 52 samples collected during Water Year 1999 and in two of the 52 samples collected during Water Year 2000. Maximum selenium concentrations reached 3.2 ug/L in Water Year 1999 and 2.3 ug/L in Water Year 2000. Data for the two sites is represented in **Figure 8**. The CCID Main Canal at the head of the San Luis Canal (sampled monthly) did not exceed 2 ug/L selenium in Water Year 1999, but contained 7 ug/L selenium in February 2000.

Figure 9 indicates the close correlation between selenium concentration in supply water as represented by the CCID Main Canal at Russell Avenue and selenium concentrations in two wetland supply canals (Agatha and Camp 13) during the two non-flood water years of 1999 and 2000. When the supply water had elevated selenium concentrations (above 2 ug/L), a corresponding increase was noted in the wetland water supply channels.

The water in the CCID Old Main Drain near the head of the San Luis Canal (sampled monthly) contained higher concentrations of selenium than that in the CCID Main Canal at the head of the San Luis Canal. The Old Main Drain had selenium concentrations greater than 2 ug/L in eight of the twelve samples during Water Year 1999 with a maximum of 7 ug/L in April. A similar pattern occurred during Water Year 2000. Since June 1998, the water from the Old Main Drain has been pumped into the Main Canal downstream of the headwork of the San Luis Canal and should not impact wetland water supplies.

Figure 7. Selenium Concentrations in the Delta Mendota Canal at Mileposts 100.85 and 110.12

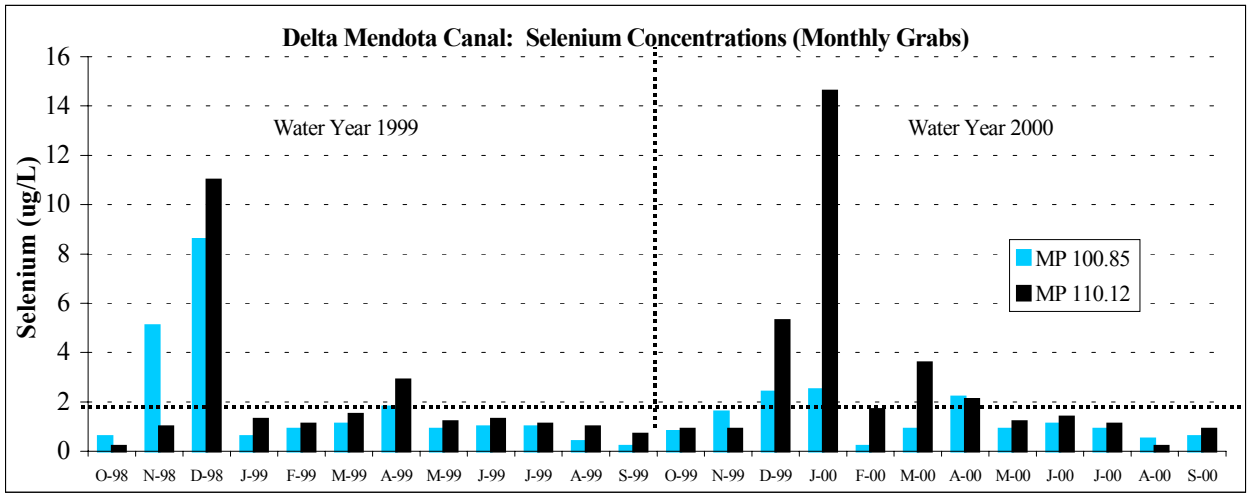


Figure 8. Selenium Concentrations in the CCID Main Canal at Bass Avenue (Monthly Grabs) and at Russell Avenue (Weekly Grabs): Water Years 1999 and 2000.

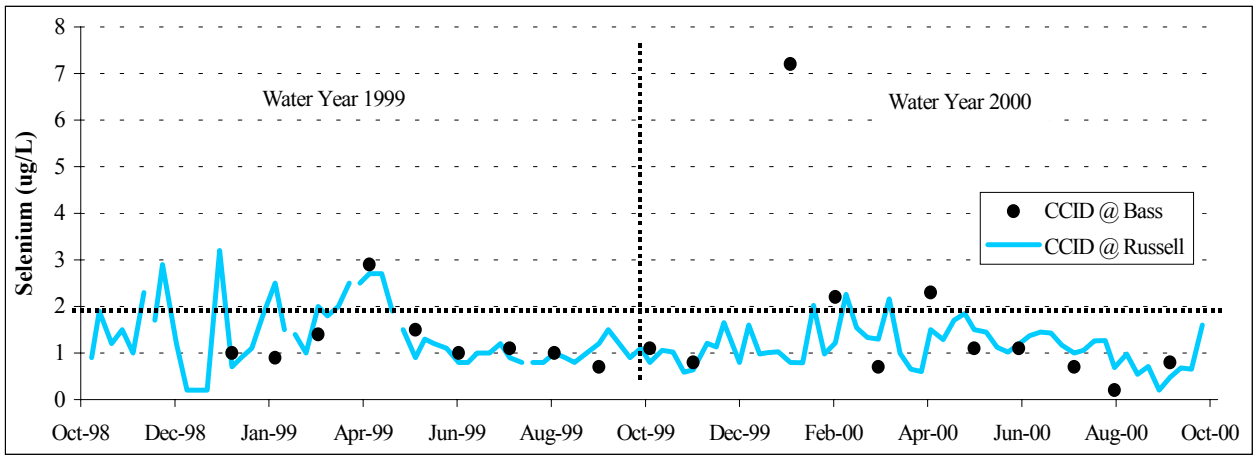


Table 6a. Selenium Concentrations in Supply Water for the Grassland Watershed: Water Year 1999

	Selenium Concentration (ug/L)						
Date	Delta Mendota Canal MP 100.85	Delta Mendota Canal MP 110.12	Mendota Pool at Mowry Bridge	CCID Main Canal at Bass Ave.	CCID Main Canal at Russell Ave.	CCID Main Canal @ Head of San Luis Canal	CCID Old Main Drain at San Luis Canal
10/08/98	0.6	<0.4	--	--	0.9 (10/7/98)	--	--
10/13/98	--	--	<2	--	1.9	<2	<2
10/21/98	--	--	--	--	1.2	--	--
10/28/98	--	--	--	--	1.5	--	--
11/04/98	--	--	--	--	1.0	--	--
11/11/98	--	--	--	--	2.3	--	--
11/12/98	5.1	1.0	--	--	--	--	--
11/18/98	--	--	--	--	1.7	--	--
11/23/98	--	--	--	--	2.9	<2	6
12/02/98	--	--	--	--	1.2	--	--
12/09/98	8.6	11		--	<0.4	--	--
12/17/98	--	--	<2	--	<0.4	<2	2
12/22/98	--	--	--	--	<0.4	--	--
12/30/98	--	--	--	--	3.2	--	--
01/08/99	0.6	1.3	--	1.0	0.7 (1/6/99)	--	--
01/13/99	--	--	--	--	0.9	--	--
01/20/99	--	--	<2	--	1.1	<2	6
01/27/99	--	--	--	--	1.8	--	--
02/04/99	0.9	1.1	--	0.9	2.5 (2/3/99)	--	--
02/10/99	--	--	--	--	1.5	--	--
02/12/99	--	--	<2	--	--	<2	<2
02/17/99	--	--	--	--	1.4	--	--
02/24/99	--	--	--	--	1.0	--	--
03/04/99	1.1	1.5	--	1.4	2.0 (3/3/99)	--	--
03/10/99	--	--	--	--	1.8	--	--
03/17/99	--	--	--	--	2.0	--	--
03/24/99	--	--	--	--	2.5	--	--
03/26/99	--	--	2.3	--	--	2	6
03/31/99	--	--	--	--	2.5	--	--
04/06/99	1.8	2.9	--	2.9	2.7 (4/7/99)	--	--
04/14/99	--	--	--	--	2.7	--	--
04/21/99	--	--	--	--	1.9	--	--
04/23/99	--	--	<2	--	--	<2	7
04/28/99	--	--	--	--	1.5	--	--
05/06/99	0.9	1.2	--	1.5	0.9 (5/7/99)	--	--
05/12/99	--	--	--	--	1.3	--	--
05/18/99	--	--	<2	--	1.2	<2	5
05/26/99	--	--	--	--	1.1	--	--
06/03/99	1.0	1.3	--	1.0	0.8 (6/2/99)	--	--
06/09/99	--	--	--	--	0.8	--	--
06/15/99	--	--	<2	--	1.0	<2	4
06/23/99	--	--	--	--	1.0	--	--
06/30/99	--	--	--	--	1.2	--	--
07/06/99	1.0	1.1	--	1.1	0.9 (7/7/99)	--	--
07/14/99	--	--	--	--	0.8	--	--
07/16/99	--	--	<2	--	--	<2	5
07/21/99	--	--	--	--	0.8	--	--
07/28/99	--	--	--	--	0.8	--	--
08/04/99	0.4	1.0		1.0	1.0	--	--
08/11/99	--	--	--	--	0.9	--	--
08/17/99	--	--	2	--	0.8	<2	3
08/25/99	--	--	--	--	1.0	--	--
09/02/99	<0.4	0.7	--	0.7	1.2 (9/1/99)	--	--
09/08/99	--	--	--	--	1.5	--	--
09/15/99	--	--	--	--	1.2	--	--
09/22/99	--	--	--	--	0.9	--	--
09/29/99	--	--	--	--	1.1	--	--

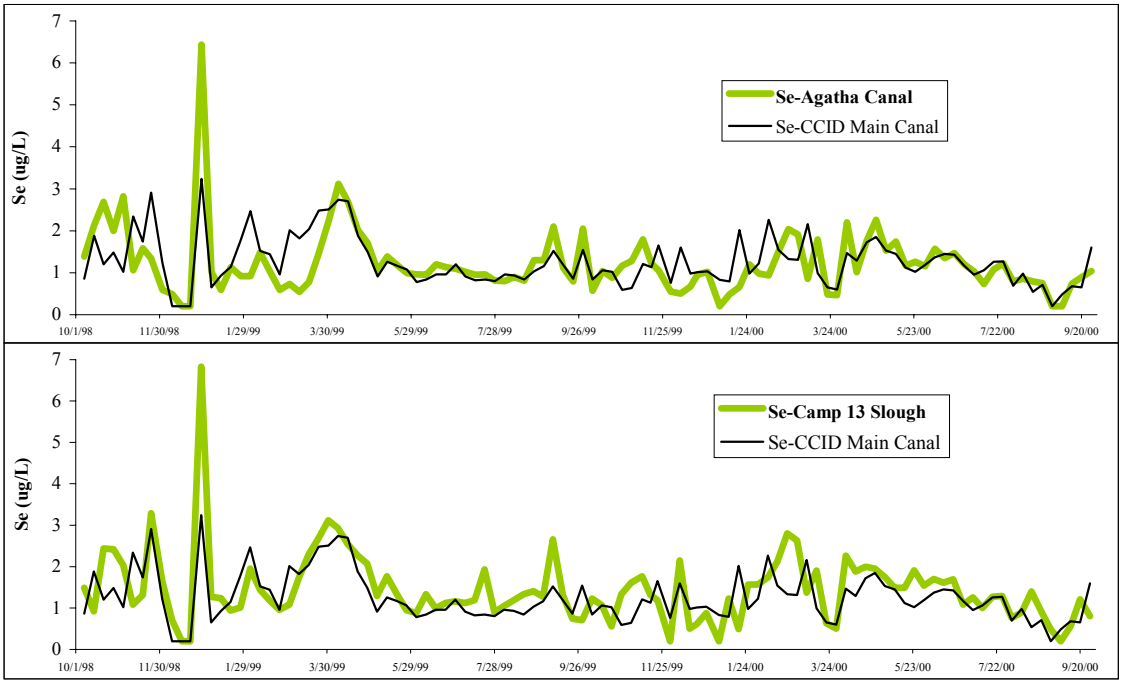
Delta Mendota Canal and CCID Main @ Bass Ave. data provided by USBR: Selenium analyses done by SDSU.
CCID Main @ San Luis Canal and Mendota Pool data provided by Summers Engineering and CCID; selenium analyses done by BSK, Fresno CA.
CCID Main @ Russell data provided by CVRWQCB; samples taken by Panoch Water District; selenium analyses done by Weck Labs, Industry CA.

Table 6b. Selenium Concentrations in Supply Water for the Grassland Watershed: Water Year 2000

	Selenium Concentration (ug/L)						
Date	Delta Mendota Canal MP 100.85	Delta Mendota Canal MP 110.12	Mendota Pool at Mowry Bridge	CCID Main Canal at Bass Ave.	CCID Main Canal at Russell Ave.	CCID Main Canal @ Head of San Luis Canal	CCID Old Main Drain at San Luis Canal
10/05/99	0.8	0.9	--	1.1	0.8 (10/6/99)	--	--
10/13/99	--	--	--	--	1.1	--	--
10/20/99	--	--	--	--	1.0	--	--
10/27/99	--	--	--	--	0.6	--	--
11/02/99	1.6	0.9	--	0.8	0.6	--	--
11/11/99	--	--	--	--	1.2	--	--
11/17/99	--	--	--	--	1.1	--	--
11/22/99	--	--	--	--	1.7	--	--
12/02/99	2.4	5.3	--	--	0.8 (12/1/00)	--	--
12/08/99	--	--	--	--	1.6	--	--
12/15/99	--	--	--	--	1.0	--	--
12/20/99	--	--	--	--	1.0	--	--
12/27/99	--	--	--	--	1.0	--	--
01/04/00	2.5	14.6	--	7.2	0.8 (1/5/00)	--	--
01/12/00	--	--	--	--	0.8	<2	4
01/19/00	--	--	--	--	2.0	--	--
01/26/00	--	--	--	--	1.0	--	--
02/02/00	<0.4	1.7	--	2.2	1.2	--	--
02/09/00	--	--	--	--	2.3	--	--
02/16/00	--	--	--	--	1.5	7	6
02/23/00	--	--	--	--	1.3	--	--
02/29/00	0.9	3.6	--	0.7	1.3 (3/1/00)	--	--
03/08/00	--	--	--	--	2.2	--	--
03/15/00	--	--	<2	--	1.0	<2	6
03/22/00	--	--	--	--	0.7	--	--
03/29/00	--	--	--	--	0.6	--	--
04/04/00	2.2	2.1	--	2.3	1.5 (4/5/00)	--	--
04/12/00	--	--	--	--	1.3	--	--
04/21/00	--	--	4.0	--	1.7 (4/19/00)	<2	6
04/26/00	--	--	--	--	1.9	--	--
05/02/00	0.9	1.2	--	1.1	1.5 (5/3/00)	--	--
05/10/00	--	--	--	--	1.5	--	--
05/17/00	--	--	<2	--	1.1	<2	4
05/24/00	--	--	--	--	1.0	--	--
05/31/00	1.1	1.4	--	1.1	1.2	--	--
06/07/00	--	--	--	--	1.4	--	--
06/14/00	--	--	<2	--	1.5	<2	4
06/21/00	--	--	--	--	1.4	--	--
06/28/00	--	--	--	--	1.2	--	--
07/06/00	0.9	1.1	--	0.7	1.0 (7/5/00)	--	--
07/12/00	--	--	<2	--	1.1	<2 (7/14/00)	4
07/19/00	--	--	--	--	1.3	--	--
07/26/00	--	--	--	--	1.3	--	--
08/01/00	0.5	<0.4	--	<0.4	0.7	--	--
08/09/00	--	--	--	--	1.0	--	--
08/16/00	--	--	<2	--	0.5	<2	4
08/23/00	--	--	--	--	0.7	--	--
08/30/00	--	--	--	--	<0.4	--	--
09/06/00	0.6	0.9		0.8	0.5	--	--
09/13/00	--	--	--	--	0.7	<2	2
09/20/00	--	--	<2	--	0.7	--	--
09/27/00	--	--	--	--	1.6	--	--

Delta Mendota Canal and CCID Main @ Bass Ave. data provided by USBR: Selenium analyses done by SDSU.
CCID Main @ San Luis Canal and Mendota Pool data provided by Summers Engineering and CCID; selenium analyses done by BSK, Fresno CA.
CCID Main @ Russell data provided by CVRWQCB; samples taken by Panoch Water District; selenium analyses done by Weck Labs, Industry CA.

Figure 9. Selenium Concentrations in CCID Main Canal as Compared to Agatha Canal and Camp 13 Slough: Water Years 1999 and 2000



Subsurface Drainage from Outside of the DPA

Subsurface drainage from outside of the DPA may discharge to the channels from two areas: western areas flowing into the Almond Drive Drain; and the Poso Drain Area. Discharges from the Almond Drain were diverted downstream of the San Luis Canal intake in Water Year 1999, and were therefore not anticipated to impact that supply channel or downstream wetland habitat.

During Water Year 1999, selenium concentrations in the Poso Drain were highly variable with concentrations at the upstream Russell Boulevard site ranging from <2 ug/L to 39 ug/L and concentrations at the downstream site (Mallard Road) ranging from <2 ug/L to 24 ug/L. Flows at the upstream site are dominated by surface and subsurface agricultural discharges while the downstream site may also receive discharges from wetland habitat.

During June 1999, a change in drainage management occurred in order to reduce subsurface drainage selenium concentrations in the Rice (Poso) Drain (Summers Engineering, July 2001). After June 1999, more tail water was discharged through the Rice Drain at Russell. Subsequently, selenium concentrations at all three Rice Drain sites mirrored each other very closely with upstream concentrations only slightly higher than downstream concentrations (Figure 6). Overall concentrations also were lower with a maximum near 20 ug/L occurring during the pre-irrigation/duck club drainage season (March). Mean selenium concentrations continued to remain above 2 ug/L at all the Rice Drain sites. The subsurface drainage discharges currently dominating the Rice Drain's flows are scheduled to either be diverted into the Grassland Bypass or recycled on farm by Water Year 2002. Monitoring will continue in the Rice (Poso) Drain to evaluate the impact of the removal of subsurface drainage on selenium concentrations in the drain.

Other Potential Selenium Sources

Other potential sources of selenium into wetland water supply channels include tail water (surface water) runoff from irrigation and local groundwater seepage. Tail water flows and shallow groundwater selenium concentrations have not been evaluated to date. Until the major sources of selenium have been controlled, determining impacts from irrigation tail water and groundwater seepage in addition to general background concentrations will be difficult.

FUTURE ACTIVITIES

Selenium concentrations have continued to exceed 2 ug/L sporadically in wetland water supply channels in the Grassland Watershed. A number of actions by various agencies and irrigation return flow operators are being implemented, including the rerouting and reuse of subsurface drainage to prevent discharges into wetland water supply channels. To continue to evaluate the effectiveness of current and future control measures as well as to guide future efforts, the following activities are a priority:

- In cooperation with the US Bureau of Reclamation (USBR), San Luis-Delta Mendota Water Authority (SLDMWA), and other water supply agencies, continue monitoring the CCID Main Canal and other supply water on a regular basis;
- In cooperation with the USBR, SLDMWA, and Grassland Area Farmers, focus on identifying the contribution of selenium from source water and subsurface drainage from outside of the DPA through special studies;
- Evaluate results to determine if additional effort is needed to identify and/or control sources of selenium into wetland supply channels within the Grassland Watershed.

Draft water quality information from the continuing studies is available on the following Central Valley Regional Water Quality Control Board web site:

http://www.swrcb.ca.gov/rwqcb5/programs/index.html

REFERENCES

CCID (Central California Irrigation District). Mowry Bridge, CCID Main @ Head of San Luis Canal, CCID Old Main Drain @ Head of San Luis Canal Data – 1/14/98 to 8/17/99. Memo from Summers Engineering dated November, 1999.

CCID (Central California Irrigation District). Mowry Bridge, CCID Main @ Head of San Luis Canal, CCID Old Main Drain @ Head of San Luis Canal Data – 9/1/99 to 10/1/00. Memo from Summers Engineering dated March,2001.

Chilcott, J.E., Westcot, D.W., Werner, K.M., and Belden, K.K., 1988. *Water Quality Survey of Tile Drainage Discharges in the San Joaquin River Basin.* California Regional Water Quality Control Board, Central Valley Region Report.

Chilcott, J., L. Grober, A. Vargas and J. Eppinger 2000. *Agricultural Drainage Contribution to Water Quality in the Grassland Watershed of Western Merced County, California: October 1997 - September 1998 (Water Year 1998).* California Regional Water Quality Control Board, Central Valley Region. 63 pages

Chilcott, J. 2000. *Review of Selenium Concentrations in Wetland Water Supply Channels in the Grassland Watershed.* California Regional Water Quality Control Board, Central Valley Region. 25 pages

RWQCB (California Regional Water Quality Control Board, Central Valley Region). 1998. *The Water Quality Control Plan (Basin Plan) for the California Regional Water Quality Control Board, Central Valley Region,Fourth Edition: The Sacramento River Basin and the San Joaquin River Basin.*

SWRCB (State Water Resources Control Board, Cal EPA). 1995. *Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary.*

Skorupa, J.P., 1998. *Selenium Poisoning of Fish and Wildlife in Nature: Lessons from Twelve Real-World Examples,* in W. Frankenberger and R. A. Engberg, eds., Environmental Chemistry of Selenium. Marcel Dekker Inc., New York, Chapter 18, pages 315 to 354.

Summers Engineering. Poso (Rice) Drain Data – 10/7/98 to 9/29/99. Memo from Joseph C. McGahan dated November, 1999.

Summers Engineering. Poso (Rice) Drain Data – 10/1/99 to 10/1/00. Memo from Joseph C. McGahan dated March, 2001.

Summers Engineering. Poso (Rice) Drain Information. Personal Communication from Joseph C. McGahan dated July, 2001.

USBR (US Bureau of Reclamation). Delta-Mendota Canal Monitoring Program Data – 1/4/95 to 11/2/99. Personal communication via Victor Stokmanis, Staff member USBR.

USBR (US Bureau of Reclamation). Delta-Mendota Canal Monitoring Program Data – 1/4/99 to 1/4/00. e-mail via Victor Stokmanis, Staff member USBR.

APPENDIX A

Comparison of Selenium Data for Water Years 1998, 1999 and 2000 Without the Inclusion of February and March Data (Stormwater Months: 1998).

Date*	CCID 98	Camp13 98	Agatha 98	SFC 98	SLC 98	CCID 99	Camp13 99	Agatha 99	SFC 99	SLC 99	CCID 00	Camp13 00	Agatha 00	SFC 00	SLC 00
10/7		1.1	0.8	1.3	1.7	0.9	1.5	1.4	1.1	1.5	0.8	1.2	0.6	1.3	0.9
10/14		1.0	0.7	1.6	2.1	1.9	0.9	2.1	2.0	2.3	1.1	1.1	1.0	0.8	0.9
10/21		0.8	0.8	1.3	2.0	1.2	2.4	2.7	1.1	2.5	1.0	0.6	0.9	0.9	1.1
10/28	0.7	0.8	1.0	1.1	1.1	1.5	2.4	2.0	1.6	1.2	0.6	1.3	1.2	0.8	0.9
11/4		0.8	0.7	0.9	0.8	1.0	2.0	2.8	1.4	2.3	0.6	1.6	1.3	0.8	1.5
11/11		0.7	0.9	1.1	1.1	2.3	1.1	1.1	1.3	1.4	1.2	1.8	1.8	0.7	1.1
11/18		1.6	1.8	1.1	1.4	1.7	1.3	1.6	1.1	1.3	1.1	1.3	1.2	0.9	1.6
11/24		1.6	1.7	1.1	2.0	2.9	3.3	1.3	1.0	3.1	1.7	1.2	1.1	0.8	1.6
12/2		8.4	1.9	2.9	7.2	1.2	1.7	0.6	0.8	1.6	0.8	<0.4	0.6	0.7	0.8
12/9		5.2	0.9	1.2	2.0	<0.4	0.7	0.5	0.8	1.0	1.6	2.2	0.5	1.3	1.3
12/16		8.9	1.5	1.1	1.3	<0.4	<0.4	<0.4	0.8	0.5	1.0	0.5	0.7	1.1	1.8
12/22		1.6	0.9	1.4	1.4	<0.4	<0.4	<0.4	0.8	<0.4	1.0	0.6	1.0	0.8	0.5
12/30		0.8	5.9	1.3	1.2	3.2	6.8	6.4	1.0	2.9	1.0	0.9	1.0	0.9	0.8
1/6		1.0	0.7	1.0	1.0	0.7	1.3	1.0	2.2	1.4	0.8	<0.4	<0.4	0.5	<0.4
1/13		1.2	1.2	1.4	1.8	0.9	1.2	0.6	2.0	1.6	0.8	1.2	0.5	0.5	1.0
1/20		1.7	1.6	0.9	1.4	1.1	0.9	1.1	1.1	1.3	2.0	0.5	0.7	0.6	0.8
1/27		1.6	1.5	1.3	1.5	1.8	1.0	0.9	2.5	1.9	1.0	1.6	1.2	0.8	1.3
FEB & MAR															
4/7	3.4	9.8	1.8	3.4	3.3	2.7	2.9	3.1	1.8	2.9	1.5	2.3	2.2	1.2	2.7
4/14	2.2	7.3	2.2	3.1	3.4	2.7	2.5	2.7	1.6	2.7	1.3	1.9	1.0	1.4	1.3
4/21	1.1	1.7	2.3	1.8	1.8	1.9	2.3	2.0	2.0	2.6	1.7	2.0	1.8	2.3	1.8
4/28	1.0	1.1	1.9	1.7	1.4	1.5	2.1	1.7	2.2	1.9	1.9	2.0	2.3	2.0	2.4
5/5	1.3	1.6	1.4	1.6	1.8	0.9	1.3	1.0	1.4	1.2	1.5	1.8	1.5	2.3	1.7
5/12	0.8	1.6	1.0	1.5	2.0	1.3	1.8	1.4	1.7	2.1	1.5	1.5	1.7	2.1	2.0
5/19	0.6	1.3	0.9	1.9	1.5	1.2	1.3	1.2	1.4	1.4	1.1	1.5	1.2	1.5	1.5
5/26	0.6	0.8	1.0	2.0	1.6	1.1	1.0	1.0	1.7	1.3	1.0	1.9	1.3	1.5	1.5
6/2	0.7	1.7	0.7	1.2	1.5	0.8	0.9	1.0	1.3	1.1	1.2	1.5	1.2	1.8	1.5
6/9	0.6	2.5	0.7	1.0	1.5	0.8	1.3	1.0	1.8	3.0	1.4	1.7	1.6	2.1	2.0
6/16	1.1	1.8	0.6	1.2	1.4	1.0	1.0	1.2	2.1	2.4	1.5	1.6	1.4	1.8	2.6
6/23	1.1	1.0	0.6	1.2	1.6	1.0	1.1	1.1	1.8	2.2	1.4	1.7	1.5	1.7	2.7
6/30	<0.4	0.7	<0.4	1.7	1.1	1.2	1.2	1.1	1.9	2.4	1.2	1.1	1.2	2.2	2.3
7/7	<0.4	<0.4	<0.4	0.7	1.6	0.9	1.1	1.0	2.0	2.3	1.0	1.3	1.0	2.5	2.2
7/14	<0.4	<0.4	<0.4	1.1	1.6	0.8	1.2	1.0	1.7	2.0	1.1	1.0	0.7	1.7	2.2
7/21	0.9	2.6	0.4	1.5	2.6	0.8	1.9	1.0	2.1	2.1	1.3	1.3	1.1	1.8	2.3
7/28	0.8	1.0	1.5	1.9	2.5	0.8	0.9	0.8	1.6	2.1	1.3	1.3	1.2	2.0	2.6
8/4	1.2	1.3	1.4	2.1	2.2	1.0	1.1	0.8	2.5	1.7	0.7	0.8	0.8	1.8	1.8
8/11	0.9	2.0	1.3	1.6	2.0	0.9	1.2	0.9	2.1	1.5	1.0	0.9	0.9	1.9	1.8
8/18		2.1	1.1	1.8	3.0	0.8	1.3	0.8	2.5	1.5	0.5	1.4	0.8	1.4	1.8
8/25	0.8	1.3	1.2	1.4	1.8	1.0	1.4	1.3	2.1	1.6	0.7	0.9	0.8	1.8	1.7
9/1	1.1	1.1	1.2	1.8	1.5	1.2	1.3	1.3	1.6	1.4	<0.4	0.5	<0.4	0.7	0.8
9/8	0.9	1.5	1.5	1.7	1.9	1.5	2.7	2.1	1.8	2.5	0.5	<0.4	<0.4	0.5	0.4
9/15	1.2	1.0	1.1	1.2	1.2	1.2	1.3	1.1	1.2	1.7	0.7	0.6	0.7	0.5	0.6
9/22	1.7	1.1	1.5	1.6	1.4	0.9	0.7	0.8	1.0	1.1	0.7	1.2	0.9	1.0	0.8
9/29	1.3	0.7	0.7	1.1	1.1	1.1	0.7	2.1	1.7	0.9	1.6	0.8	1.0	2.0	1.8
	CCID 98	Camp13 98	Agatha 98	SFC 98	SLC 98	CCID 99	Camp13 99	Agatha 99	SFC 99	SLC 99	CCID 00	Camp13 00	Agatha 00	SFC 00	SLC 00
Count	26	43	43	43	43	43	43	43	43	43	43	43	43	43	42
Min	<0.4	<0.4	<0.4	0.7	0.8	<0.4	<0.4	<0.4	0.8	<0.4	<0.4	<0.4	<0.4	0.5	<0.4
Max	3.4	9.8	5.9	3.4	7.2	3.2	6.8	6.4	2.5	3.1	2.0	2.3	2.3	2.5	2.7
Mean	1.0	2.0	1.2	1.5	1.8	1.3	1.5	1.4	1.6	1.8	1.1	1.2	1.1	1.3	1.5
Geo Mean	0.8	1.4	1.0	1.4	1.7	1.1	1.3	1.2	1.5	1.6	1.0	1.1	0.9	1.2	1.4
Median	0.9	1.3	1.1	1.4	1.6	1.1	1.3	1.1	1.7	1.7	1.1	1.3	1.0	1.3	1.6

* Date approximate to within three days